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Rover Mounted Ground Penetrating Radar as a Tool for Investigating the Near-Surface of Mars and Beyond; J.A. Grant and P.H. Schultz, Brown University, Providence, RI 02912.

Introduction: In spite of the highly successful nature of recent planetary missions to the terrestrial planets and outer satellites a number of questions concerning the evolution of their surfaces remain unresolved. For example, knowledge of many characteristics of the stratigraphy and soils comprising the near-surface on Mars remains largely unknown, but is crucial in order to accurately define the history of surface processes and near-surface sedimentary record. Similar statements can be made regarding our understanding of near-surface stratigraphy and processes on other extraterrestrial planetary bodies. Ground penetrating radar (GPR) is a proven and standard instrument capable of imaging the subsurface at high resolution to 10's of meters depth in a variety of terrestrial environments (e.g. 1-5). Moreover, GPR is portable and easily modified for rover deployment. Data collected with a rover mounted GPR could resolve a number of issues related to planetary surface evolution by defining shallow stratigraphic records and would provide context for interpreting results of other surface analyses (e.g. elemental or mineralogical). A discussion of existing GPR capabilities is followed first by examples of how GPR might be used to better define surface evolution on Mars and then by a brief description of possible GPR applications to the Moon and other planetary surfaces.

GPR on the Earth: Terrestrial experience with GPRs outfitted with transducers having frequencies of 50 to 500 MHz demonstrates the ability of instrument to define stratigraphy up to 30-40 m depth (1) and a vertical/horizontal resolution of up to ~10 cm (2,3). Moreover, successful GPR deployment in and around Meteor Crater, Arizona, Odessa Craters, Texas, and the Rio Cuarto Craters, Argentina, illustrates the capabilities of GPR in somewhat analogous planetary settings (2,3). Data collected along short transects (10-100 m) at these impact sites with an analogue GPR yielded stratigraphic markers corresponding to ejecta, alluvium, calcic soils, and *in situ* bedrock (Figs. 1 and 2), all possessing dielectric constants between 4-10. Prominent stratigraphic reflectors were identified even where calcic soils were well developed (Fig. 2). GPR data from other terrestrial settings distinguishes bedding planes in bedrock (4) and lacustrine sediments beneath a thick ice cover (5). These characteristics coupled with the probability that a planetary GPR would possess only ~2-3 kg mass, occupy less than 2000 cm^3, use ~10-15 watts, and operate at low temperatures, implies GPR could define shallow martian stratigraphy and should be considered for future rover missions.

GPR on Mars: Definition of shallow stratigraphy on Mars using a rover mounted GPR could answer a range of questions regarding surface evolution when accompanied by ground truth from penetrators or cores. Locally, GPR could define the occurrence of sulphur-enriched duricrusts (6): a varying distribution of the deposits supports a groundwater source (6) while uniform, discretely layered accumulations imply fallout of aerosols (7). GPR might also be used to identify carbonates that may have formed in the regolith (8), but are poorly detected telescopically (9). The radar would also test models of ground ice/water distribution (e.g. 10) or for the presence of near-surface brines (11-12). Even without ground truth, GPR would define shallow stratigraphic complexity, thereby providing context for interpreting data from other instruments and identifying future coring locations.

On a broader scale, GPR could be used to constrain the nature and origin of fine-grained deposits that mantle portions of the cratered uplands on Mars (e.g. 13-14) and preserve the long-term sedimentary history of surface-atmosphere exchanges. Moreover, GPR transects within the northern lowlands plains should distinguish characteristic stratigraphy and structure that would help identify whether alluvial, volcanic, eolian (e.g. 15), pelagic (16), and/or some other process(es) are responsible for their origin. For example, GPR definition of laterally discontinuous, either poorly sorted and crudely layered deposits or better sorted, more uniformly bedded bar and swale features would suggest that alluvial processes created the lowlands plains. Conversely, identification of continuously bedded, well-sorted and fine-grained deposits devoid of bedforms, but possibly interbedded with coarser turbidites is more indicative of pelagic deposition. Volcanic and eolian beds can be similarly characterized (e.g. through the presence of characteristic fracture patterns, or bedforms).

GPR on Other Planets: GPR data collected at terrestrial impact sites discriminates *in situ* bedrock, ejecta, alluvium, and soils, thereby highlighting the potential of the instrument for investigating the dry surface of the Moon as well as other satellites and planets. Inclusion of a GPR on a lunar rover would allow high resolution definition of shallow stratigraphy when interpreted using existing data on lunar dielectric properties (17) and more general results from the Apollo lunar sounder (18). In mare regions, GPR might define lava flow thicknesses, detect underlying basement topography along marginal areas, and locate lava tubes or other buried volcanic structures, some of which may be hazards to avoid during subsequent missions. Collectively, this information could verify compositional units defined by other instruments (19). On the surfaces of the icy Galilean satellites, GPR could be used to characterize any regolith, identify possible water ice dikes, further define near–surface stress patterns, or determine the near–surface distribution of ice versus rocky material (20).

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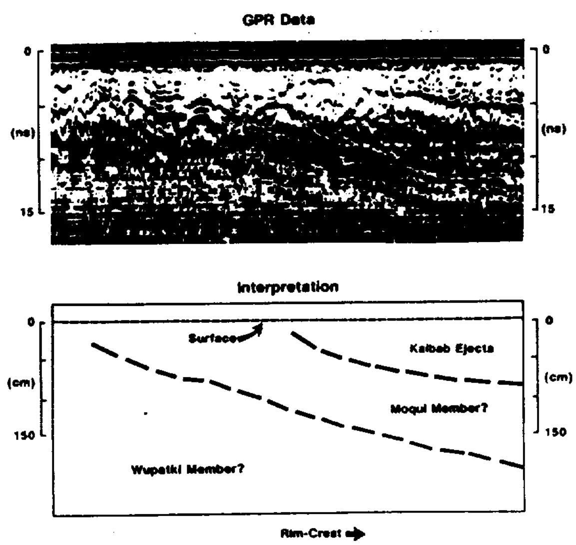

Figure 1. Analogue GPR transect from N to S across the distal edge of the continuous ejecta ~1.3 km south of Meteor Crater (GPR supplied by Geophysical Survey Systems, Inc.). Radar pulse travel time is in nanoseconds and the depth is in cm. Transducer frequency is 500 MHz. Ejecta comprised primarily of ejected Kaibab Formation fragments directly superposes *in situ* Moqui and deeper Wupatki Members of the Moenkopi Formation. Interpretations were confirmed by excavation and/or tracing reflectors to outcrop.

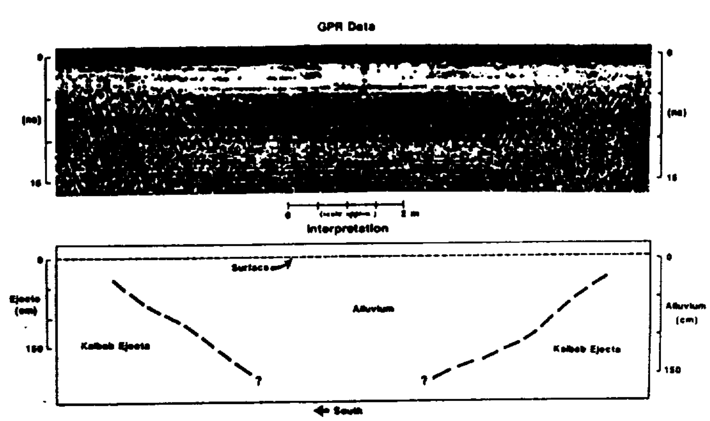

Figure 2. Analogue GPR transect from SE to NW across alluvium ~0.9 km S of Meteor Crater (GPR supplied by Geophysical Survey Systems, Inc.). Radar pulse travel time is in nanoseconds and the depth is in cm. Transducer frequency is 500 MHz. Kaibab ejecta and alluvium are clearly distinguished as is the top of a calcic soil horizon (Bk horizon) at ~50 cm depth (top of dark zone in alluvium). Discontinuous reflectors in the ejecta are caused by buried blocks. Contacts were confirmed by excavation.